not called in a physician, thus never came within the knowledge of the board of health. Other cases have closely resembled chicken-pox and have been diagnosed as such.

The board of health has made every effort to quietly stamp out the smallpox and prevent its assuming the proportions of an epidemic.

But largely because of the mild type and more because so large a number of people are not protected by vaccination, the situation is in danger of becoming epidemic. The board of health therefore advises as the most efficient means of preventing this threatened epidemic that every person who has not been successfully vaccinated within the past six years be vaccinated without delay.

The board does not wish to close the public schools, churches, picture shows, etc.; but this will be inevitable if smallpox does become epidemic.

We further urge upon the board of education that they require the vaccination of all school children; upon employers of labor, that they require vaccination of their employees; upon those in authority that they require vaccination of the pupils of the parochial schools; upon all citizens who become sick with any thing that resembles an eruptive fever, that they call in a physician without delay.

Without the cooperation of the public in this matter of vaccination, it will not be possible to stop the spread of smallpox, and it is within the power of the public to stop this outbreak by being generally vaccinated.

It is up to you to do your part.

THE BOARD OF HEALTH,
By FAY KILBOURNE, *Clerk.*

IMPOUNDED WATER.

SOME GENERAL CONSIDERATIONS ON ITS EFFECT ON THE PREVALENCE OF MALARIA.

By H. R. CARTER, Senior Surgeon, United States Public Health Service.

A malarial survey of certain impounded waters has been undertaken by the Public Health Service. The object of this survey is to determine (1) the influence such waters exert on the incidence of malaria; (2) what conditions affect this influence for good or for ill; and (3) what measures can be taken to minimize the ill effect of such waters and to increase to a maximum their good effect.

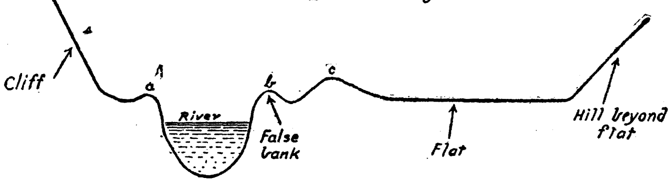
The problem is an important one. It concerns the ponds of many of the large power plants which are utilizing water power. I believe that a conservative estimate of the amount of money invested in such plants in the malarial section of the United States would be over one hundred million dollars, with more than that much in those projected. The single plant at Whitney, N. C., for the manufacture of aluminum, is estimated to cost twenty-three million. The utilization of water power is not like the consumption of coal. It does not lessen a natural resource of the country; it is a true conservation of wasted power and adds to the permanent assets of the country. Also, it is a mighty factor in the development of the country—much in excess of the money cost of the power plant. If the ponds of these power plants are a serious menace to the health of the community, they can not be allowed or, if allowed, they render unhealthful a considerable area adjacent to them. In either case the loss is a serious one.

Nor are the small ponds of the grist-milling, cotton, or other neighborhood industries—important from their number—less involved. The effect of such ponds in producing malaria is a subject of complaint in many communities. Some of these complaints are doubtless well founded and some have less reason for their basis. It is obviously important, then, to determine what effect these ponds have in producing malaria and what measures should be taken to minimize this effect, which is the ultimate practical end of our problem.

Unquestionably, any considerable disturbance of the earth's surface in a country subject to malaria will affect the conditions of mosquito breeding and therefore the prevalence of malaria in its neighborhood. This is true of the construction of dams for mpounding water, of railroads, or even of ordinary roads. I think we can say that, as a result of such construction, breeding places will be increased in some places and diminished in others. Since malaria

Fig. 1.

Cross section of River Valley.



Altitudes of elevations at - a, b, &c. exaggerated.
U S. Public Health Service

has generally been associated with standing water, bad effects will be more readily ascribed to the construction of dams impounding water than to railroads or other works which may also affect its prevalence. I have often seen breeding places removed by railroad ditches draining them and more often seen breeding places made by borrow pits or by railroad embankments blocking drainage.

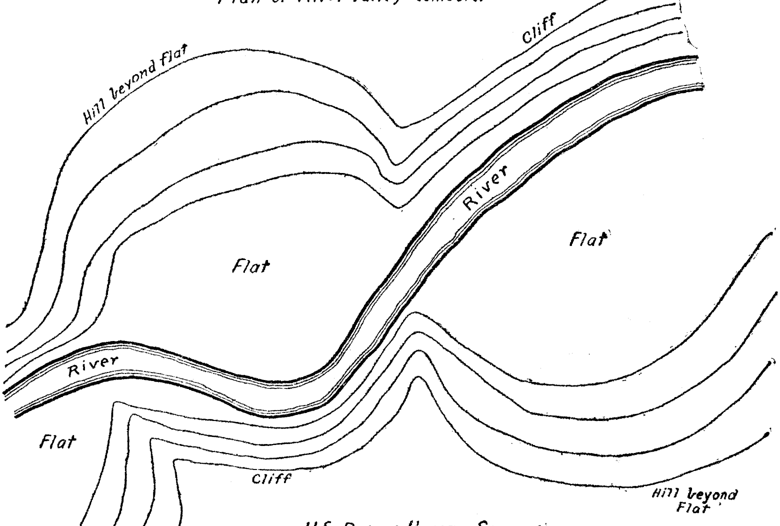
The dams of the large power plants which we would consider are situated on the eastern slope of the Appalachians in the uplands between the flat country and the mountains. Below this there is not fall enough to justify a dam. The region above is outside the malarial district.

The Normal River Valley.

The general configuration of a river valley in this section is about as follows: On one side of the river is a cliff and on the other a flat—the "river bottom." The cliffs and flats alternate on the same side of the river, but in general they face each other across the river. Rarely does a cliff face a cliff or a flat another flat for a considerable distance, although, of course, the river does sometimes run in a gorge or between flats.

The cliff comes down steeply to a plateau a few feet or yards wide on the bank of the river. The flat is highest just at the river bank and extends back to the hills. Skirting the base of the hills there is, I may almost say invariably, a marsh or a marshy stream. Sometimes this is quite extensive, sometimes simply a series of small marshes fairly extensive in the aggregate. It is caused by the seepage water from the hills. The flat is usually sandy and does not hold water except (1) where there is continued seepage and (2) where the surface has been scoured off by freshets and has left the more impermeable soil exposed. Quite generally it is crossed by ditches and sluggish streams.

Fig. 2.
Plan of River Valley contours.



U.S. Public Health Service.

The river flows normally between fairly deep banks, say 4 to 8 feet below them, with occasionally a "false bank" on the side next the flat. This is a shelf scoured out above the normal water level, but below—2 to 4 feet—the level of the true bank of the river. These may be quite wide—10 to 40 yards—and may be covered more or less with vegetation. Into the river empty creeks, branches, and ravines. When a creek or branch comes in between cliffs its entrance and banks are usually clean. When it comes through a flat, or skirting between a flat and a hill, there are generally marshes on its banks, or on one bank, as it crosses the flat.

In such a valley, then, there are places physically suitable for breeding Anopheles, normally existing on every river bottom, especially at the bases of the surrounding hills.

The Normal Pond.

When a dam is built for a power plant it is high enough to cause the waters near the dam to cover the flat and come well up on the hills back of it. The result at this place is a sheet of water filling the valley from the cliff on one side to the hills beyond the flat on the other with deep water against steep banks on both sides. This, obviously, is not suitable for breeding mosquitoes, and the covering up of the marshes and other places physically suitable for breeding mosquitoes on the flats markedly lessens the number of such places near the dam. As we go up the river toward the head of "backwater," there will be, on account of the gradual rise of the normal river bed and valley, some place where the pond just overflows, or nearly overflows, the flats, and produces physical conditions very suitable for breeding mosquitoes. Above this zone the river is confined to its banks, and its effect in breeding mosquitoes is not directly affected by the dam. Up to backwater, however, wherever the elevation of the river is high enough to fill the drains of the flats and thus lessen seepage, the flats will be less well drained. In this section, too, the water will back up into the creeks and branches entering it, giving fish better access to the lower portions of the beds of these creeks and branches.

Similarly, the mouths and lower portions of creeks and branches—which are normally quite frequently marshy—are, near the dam, covered deeply by water standing against the hillsides which form the sides of the valleys of these creeks. The mouths of these creeks, then, and the marshes on their banks, are thus no longer physically suitable for breeding places. Yet, just as with the river, there should be—at least may be—a zone somewhere up the creek where the elevation of the backwater is such as to produce physical conditions well suited for mosquito breeding. This is especially true of large creeks with considerable flats on their banks. Where the valley is narrow and the sides of the valley are steep, this will not occur, or will occur only to a small extent.

Obviously, then, in normal stages of water the dam destroys some potential breeding places, near the dam especially, and makes others higher up the pond and on some of the creeks entering the pond.

Freshets.

The ill effect of a rise in a river, overflowing its banks, is that as it goes down to normal pools will be left on the banks to breed mosquitoes. When the normal river goes down after a freshet, pools of water will be left on the lowlands if the rise has been "out of banks," and these will be more or less persistent according to the permeability of the soil. A much less rise will leave pools on the "false bank" and these, the top soil being scoured off, are more permanent.

For the pond: Near the dam and wherever the waters of the pond rise against hillsides no pools would be left and consequently no ill effects received from a freshet, be it great or small. Above the zone where the pond is normally just out of banks—let us call it the "zone of overflow"—a freshet less than one that would normally cause an overflow would now cause the banks to be flooded, and, on going down, would leave pools. A full freshet would also overflow this part of the pond, but would do no more harm than if there were no pond. In the zone of overflow a freshet would do good; that is, render it less suitable for breeding mosquitoes. Below this, in the pond proper, it would have little effect.

In the creeks entering the pond, the rise, and hence backwater of the freshet, would be extended higher than the same freshet would have gone in the normal creek, and, as the water goes down, whatever effect would have been produced in the normal creek valley will be more or less produced at a higher elevation up the creek.

Obviously, the effect of a freshet is more or less proportioned to the amount of the rise. Now in proportion as the area of the pond exceeds that of the normal river so much will the rise of the pond be less than that of the river; and the rise of the freshet in the creeks entering the pond will also be less, measured from their ordinary backwater, than it would have been, measured from the level of the normal river, had there been no dam. These rises determine the land overflowed by the freshet and consequently left bare by its subsidence, both for creek and for river valley. It would seem then that the effect of the freshet would, on the whole, be lessened, and decidedly lessened, in that part of the valley covered by the pond.

General Effect of Dam.

Whether the whole effect of the dam is to lessen or increase the breeding places is a question which will have to be determined by biological study, and which doubtless will differ for different ponds. *This much is certain: The impounding of water will change the location of places physically suited for breeding.* It will move them away from the dam toward the upper reaches of the pond. It will destroy them in the lower part of the creeks which empty into the pond, possibly to increase them higher up, away from the river. A change of location of actual breeding places, the number of mosquitoes remaining the same, would in general be a disadvantage, because the locations of residences in a long-settled malarial section have been determined to an extent by the healthfulness of the location, the more malarious situations being avoided.

Conditions which Affect the Breeding of Mosquitoes in the Pond.

It is assumed that Anopheles mosquitoes do not breed in the deep open water of the pond and that only such conditions as affect the shallow water at the edges need be considered. This needs only stating.

(1) *Change of level of the pond under normal operation of power plant.*—The power in the section considered in this paper is largely used for cotton mills, and on this account the power plant is partly shut down from Saturday noon to Monday morning—about 42 hours—and the water rises in the pond during this time. This rise at Blewetts Falls, N. C., was, I was told, normally about 24 inches; it was more during the two Sundays I was there, and the fall was rapid on Monday. There is also a small rise for each night; 9 to 12 inches should be about the average at the place named above. These changes of elevation within a shorter time than the cycle of development of the mosquito should tend to prevent breeding. As the water falls it should leave some of the larvæ stranded in the grass and behind drift, while the rise would expose them to some extent to fish, from which the shallow water and other conditions at the edges had protected them. Accidental change in the environment of larvæ should work to their disadvantage, because it would be a change from the protective conditions which they themselves had established. Note that a vertical rise of 1 foot would generally cover more than 1 foot of land, measured horizontally. On a gently sloping bank, where there would most likely be breeding, it would cover 10 to 20 feet easily—a movement greater than many larvæ would be able to protect themselves against during the time of rise and fall.

(2) *Winds.*—The effect of wind is to lessen breeding on the pond. The banks will be cut steep and kept bare of growth by wave action wherever the waves can reach them—that is, in the open pond. Up the creeks and ravines the banks may be protected from this erosion by position or by growth. The former is the main factor. Similarly, the gently sloping banks in the zone where the pond is just out of banks will also escape erosion. The waves also—the effect of the wind on the pond—will drown such larvæ as are exposed to this action. Obviously, the effect of the wind is greater on the pond than on the normal river, because it is much wider and more exposed—not down under the banks.

(3) *Driftwood and floatage.*—Drift must be considered under two heads: The large pieces—driftwood—and the very small stuff—floatage—the latter being so small that it makes a covering for the water almost like scum. The effect of the two on breeding Anopheles is quite different.

Quantities of drift will be found on some portions of the banks of the pond. Especially is this found up bayous—near their mouths

and some way up. On the banks of the open pond it is less often found, although in places where the bank is protected by the roots of brush or by thick brush it is found. Some of this drift comes from the trees and bushes left in the pond. These die when flooded and their branches, etc., fall in the water. The larger part, however, seems to come from the drift brought down by freshets. The tendency of this drift is to lodge on the bank at high-water mark and be left there as the water recedes. If it can reach the bank, it does not follow the water down. This is especially true if the bank has a gentle slope; far less so against steep banks. The reason for this is obvious. This drift furnishes protection to larvæ, and thus does harm. The driftwood does not seem to furnish much protection against fish—unless, indeed, the sticks carry algæ. The floatage of small stuff, however, does protect against fish, and larvæ are frequently found in floatage when they can not be found elsewhere. No kind of drift seems to furnish much protection against wave action. Quite frequently larvæ are found in drift, evidently washed down, either as eggs or larvæ, from some place higher upstream. The writer has found but one instance in which he thought they were from eggs deposited in situ.

(4) *Bushes growing in the pond.*—These are, of course, found only in shallow water. They die, or the majority of them do, and in time disappear. Until they do disappear they do harm by preventing drift from reaching the bank, especially in deep bays, and thus grounding at high water. They also to some extent protect the shore from wave action. Such species as grow in water, as willow, tupelo gum, and sweet gum, are less apt than other species to die on account of having their roots submerged. Sweet gum was especially persistent about one pond examined.

(5) *Grass and weeds.*—The ordinary land grass dies when covered by water. That it will be replaced in time in shallow water by aquatic plants seems almost certain. This will not take place where the bank is eroded by wave action.

The presence of grass growing in shallow water should furnish protection to the larvæ from fish. In a pond examined the dead land grass was covered by silt, and no mosquitoes were breeding in the water adjacent. It had not yet been replaced by aquatic vegetation, although the pond was nearly 3 years old.

(6) *Algæ.*—The presence of algæ should influence the breeding of mosquitoes, and is therefore to be noted. They are apt to be found on sticks, leaves, etc., in clear water. Their condition as well as their occurrence is to be noted, as Anopheles are rarely, if ever, found with dead and decomposing algæ. The conditions which influence the growth of algæ—current, muddiness, sunlight, etc.—should also be noted, that we may form an idea of their permanence.

(7) *Fish and other aquatic enemies.*—The rôle of fish in preventing mosquito breeding is well known. Whether they are efficient in so doing depends on their kind, number, and access to the larvæ. It is the small top minnow that is useful, not large fish. It is of course the number in the places suitable for breeding mosquitoes that is to be considered, not the general number in the pond. Their number and efficiency will be shown by the biological survey. In a recent survey small fish were rarely found at first, the water being very muddy, while a week later, in shallow water at the edges, which had become nearly clear, they were abundant and, from the absence of larvæ, probably efficient.

There are other aquatic enemies of mosquitoes besides fish, and that the pond is a large permanent body of water is a condition favorable to their propagation. In a recent survey a "water flea," or "water boatman," was found in large numbers in water in which we might have expected to find larvæ of mosquitoes. In a large number of places examined no larvæ were found with them. These insects were identified by Mr. Allan Jennings, of the Entomological Bureau, as Hemiptera, belonging to the family *Corisidae,* genus *Corisa,* and stated to be predaceous—feeding on the larvæ of mosquitoes. The presence and efficiency of these and other similar enemies will be determined by the biological—or rather zoological—survey.

Method of Making Survey.

Since we wish to determine the whole effect of the pond on the production of malaria, we must compare the condition which existed before the pond was made with that which exists afterwards. If the malaria which the pond produces be counted a debit, the malaria it prevents must be counted a credit. It is the *change* in conditions we would know.

Obviously, then, a survey should be made of the country to be covered and affected by the pond before the pond is made. There is no other way to ascertain with certainty the normal condition of the country before the pond is made.

Unfortunately for the ponds now existing, this has not been done, and the method adopted at Blewetts Falls to determine this is probably the best that can be devised when the pond is already in existence. A section of the river valley was selected beginning a half mile below the dam and running about a mile down the river, and one beginning a mile above backwater and extending about a mile higher up the river. Both of these were carefully surveyed, physically and biologically.

It seemed fair to consider the submerged valley as being approximately like these sections. In addition, when the bayous formed by the creeks and branches running down into the pond were sur-

veyed, the examination was carried some distance above "backwater" to see what was the normal condition of the country unaffected by the pond. For creeks coming in some miles up the pond this would be the class of country covered by the pond in creek valleys entering nearer the dam. To illustrate: If the dam raised the water 40 feet and the pond was 10 miles long, the valley of a creek entering the pond at the dam would have been flooded 40 feet above the normal river level at the creek's mouth, while the valley of a creek entering 5 miles above the dam would be flooded only 20 feet, more or less, above the level of its creek's mouth as it entered the normal river. Thus the valley of the second creek, from backwater to a contour 20 feet above the pond level, would correspond to a part—the upper part—of the valley of the first creek which was flooded. If the creek were 6 miles above the dam, from backwater to a contour 24 feet above it would be taken.

In this way a pretty fair idea of the original condition of the submerged tract was obtained, but, of course, it was less accurate than that which would have been given by a survey of the tract itself before the dam was built.

The surveys of both normal river valley and the pond are to be made under two heads: Physical and zoological.

The first is to determine if the physical conditions of the places examined are such as would make them suitable breeding places for Anopheles—i. e., are they such places as we would expect to breed Anopheles, and if so, are they so situated as to produce malaria.

The second is to determine what places actually are breeding malaria-bearing mosquitoes. This survey must be most carefully made of places close enough to residences to produce malaria in men if the places were breeding Anopheles.

The physical survey of a place will then take account of the—

(1) Depth of water.

(2) Presence of pools and their nature.

(3) Nature and configuration of the banks, both vertical and horizontal.

(4) Shade and sunshine.

(5) Character of water—clear, muddy, or impregnated with iron; silt on the grass and weeds; algæ; scums, etc.

(6) Protection against (*a*) wave action which drowns the larvæ; and (*b*) the fish which eat them, especially what protection is given by aquatic or land vegetation.

(7) Proximity to source of blood supply for mosquitoes—as human beings or cattle. Breeding is usually much more marked near such places, although it does occur at long distances from any conceivable source of abundant blood supply.

(8) Distances from human residences and obstacles between the place examined and such residences. This, of course, is to determine the effect on producing malaria which such places would have if they bred malaria-bearing mosquitoes.[1]

The zoological survey will take account of—

(1) Whether Anopheles are found breeding in any place and to what extent.

(2) The species of Anopheles—whether or no it be a malarial-vector.

(3) The presence of fish and other aquatic enemies.

Under (1) one must note that Anopheles larvæ may be washed by sudden freshets from the place where the eggs were deposited and found where they lodged. The writer has seen such instances, but the larvæ so found were never in sufficient number and permanent enough to constitute a breeding place, except possibly at one place. This survey, too—the determination of the places in which malaria-bearing mosquitoes are actually breeding—may enable us to form a better idea of the physical conditions which determine their breeding.

From the foregoing it does not seem probable that Anopheles will be found breeding to a considerable extent in large ponds, except in that zone in which the banks are just overflowed, or about to be overflowed, and in creeks and branches at places where similar conditions of banks prevail. In the bayous and creeks where larvæ may be sheltered by drift and protected by the conformation of the shore from wave action some breeding will also be found.

For practical purposes—to determine what production of malaria is caused by the pond—it would be necessary to examine only such of these probable breeding places as are close enough to residences to produce malaria if these places do breed Anopheles. Roughly, a half mile would be about far enough.

The surveys at present, however, had best be made more general than this, and other places also examined, because their examination may throw light on the general problem, which is absolutely a new one. After the general problem of impounded water has been studied awhile, doubtless the work necessary to arrive at the determination of the effect of any particular pond in causing malaria will be much simplified. These surveys should be made more than once; indeed they must be made during different conditions of the water, as when muddy and clear, and at different stages of the water, naturally also, at different times of the year. Whether or no the water be muddy affects the growth of algæ, which, again, affects breeding.

[1] Possibly (7) and (8) should be considered as part of the zoological survey, but since distance is the prime factor considered they are placed here.

Obviously, too, the pond will undergo much change within the first few years of its existence. The trees and brush the roots of which are submerged will die, fall, be cast up—some of them—on the bank, and rot. I think the drift adjacent to the banks will be most abundant the first year or two. As soon as the small brush in the water next to the bank is gone, the drift will go ashore at high-water mark, lodge as the water falls, and cease to be a shelter for larvæ. The grass and weeds proper to the land will disappear and aquatic growth take its place. The banks, where exposed to wave action, will become steeper and cleaner. Small fish should, I think, greatly increase if the water is suitable, as the shallow water on the gently sloping banks of the upper parts of the pond and of the creeks should furnish them ideal breeding places. Predaceous insects should also increase in a permanent body of water. On the whole, the pond will, I think, become less suitable for breeding mosquitoes as it gets older, all factors working to this end except the growth of aquatic grasses and algæ. Upon the extent of this—the growth of aquatic vegetation and the protection it gives the larvæ from fish—will largely depend the rôle of the pond in permanently breeding mosquitoes.

AN EPIDEMIOLOGICAL STUDY OF A PLAGUE FOCUS.

By CHARLES V. AKIN, Assistant Surgeon, United States Public Health Service.

On September 25, 1914, two plague-infected female rats (*Mus norvegicus*) were taken in snap traps in New Orleans at 1013 Magazine Street, the building in which they were found being a combined stable and junk warehouse. Both rats were determined positive on the day of finding. The fact that the building is situated just across the street from 1006 Magazine Street, a previous focus in which plague-infected rodents were found on August 27, 1914, is evidence of the continuation of infection in the neighborhood, though it had been stamped out at 1006 Magazine Street. Both localities are in the heart of a belt which was heavily infected. It is believed that the infection at 1013 Magazine Street followed that at 1006 Magazine Street on account of a large number of infected rats which survived.

Notation of the architectural peculiarities of this building will perhaps be of value in determining relationship between "cause and effect" as evidenced in mice plague later found there.

The premises at 1013 Magazine Street occupy a very large lot, which is inclosed on all sides by a brick wall running to the full height of two stories. Within the inclosure were found many interesting features. This building is in the form of a great double L (L⊥T), the bar and wings being 22 feet wide, encircling on three sides an interior court, the playground of pigeons, chickens, and